

# Validation of radiances measured by CERES on Terra & Aqua

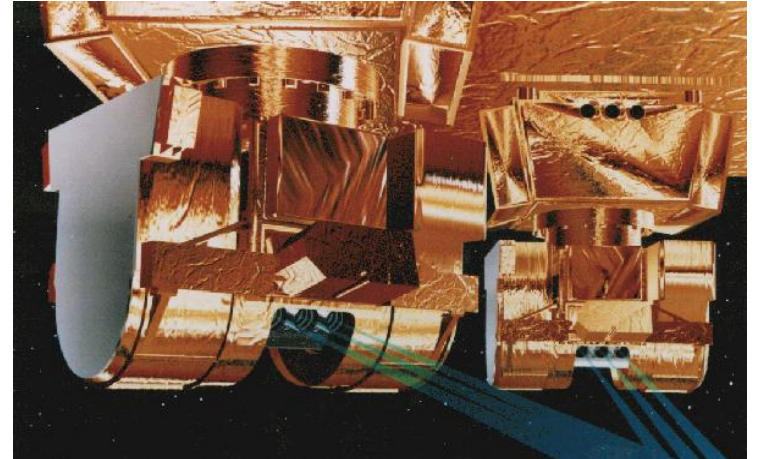
Z. Peter Szewczyk  
G. Louis Smith  
Kory J. Priestley

SPIE Conference, Barcelona 09/08-12, 2003

# Presentation Outline

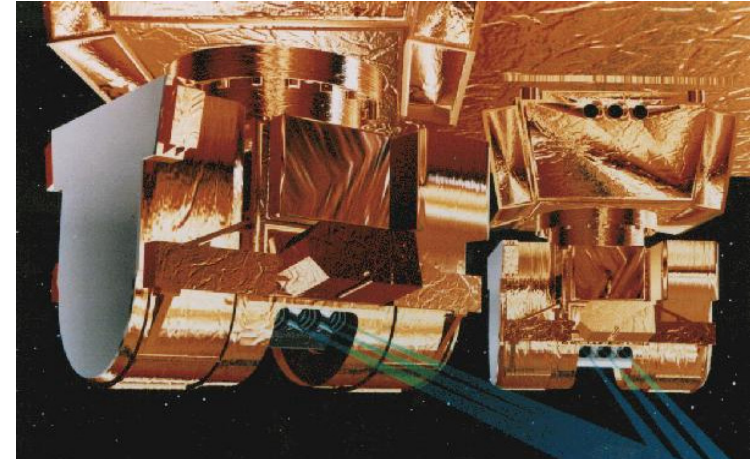
- CERES on Terra and Aqua
- Scanning experiment for validation
- Data acquisition and processing constraints
- Scatter plots of radiances
- Statistics
- Results
- Conclusions

# Clouds and the Earth's Radiant Energy System Instrument



- Narrow field-of-view (15x30km at nadir) scanning radiometer:
  - Shortwave channel (0.3-5 $\mu$ m),
  - Total channel (0.3-100 $\mu$ m),
  - Window channel (8-12 $\mu$ m)
- PFM on board TRMM (1998, failed 06/2000)
- FM1 & FM2 on board Terra (in service from 03/2000)
- FM3 & FM4 on board Aqua (in service from 06/2002)

# CERES



Calibration stability monitored with:

- On-board calibration sources (blackbodies, lamps, solar)
- Multi-channel and multi-instrument consistency
- Geophysical validation

Gain drifts can be detected at the 0.1% level, and corrected!

A part of validated data set for the radiation budget since 1984

# PAPS for validation

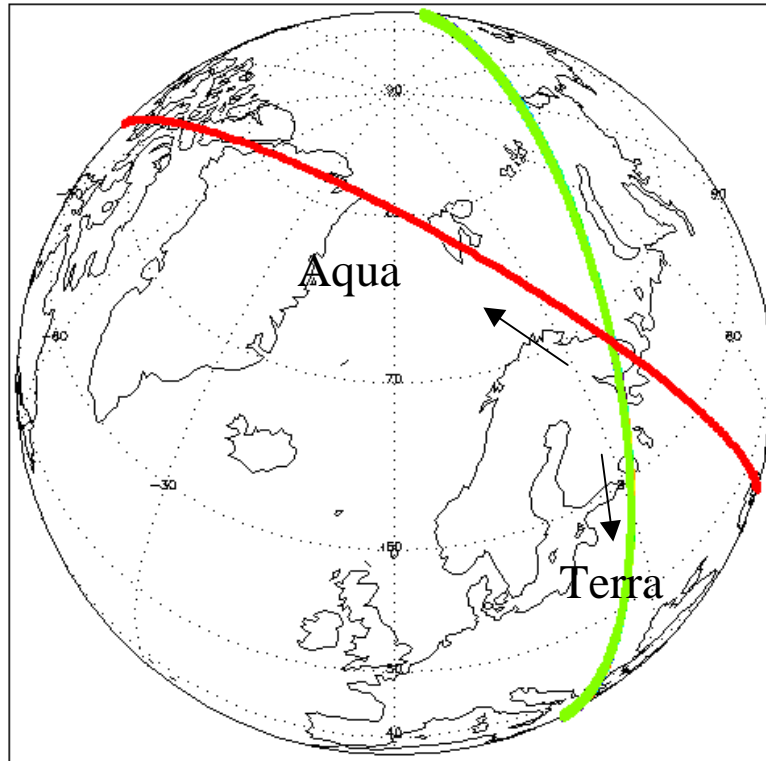
## CERES in Programmable Azimuth Plane Scan:

- Scanning Plane follows a prescribed schedule
- Matches the viewing geometry of other instruments
- Increases sampling by an order of magnitude

## Examples:

- CERES/TRMM vs. ScaRaB/Resurs (1998)
- CERES/TRMM vs. CERES/Terra (2000)
- CERES/Terra vs. CERES/Aqua (2002)

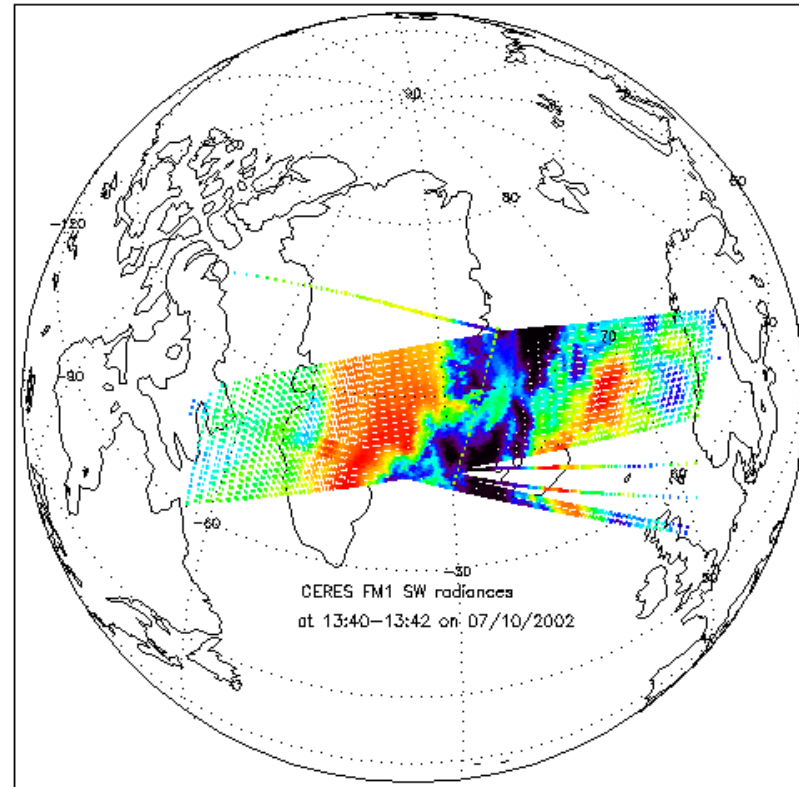
# Terra & Aqua orbits



- Sun-synchronous, inclination angle  $98.2^\circ$  and  $81.8^\circ$
- Equator crossing time: 10:30AM and 1:30PM
- about 15 minutes apart at nodes

# FM1 scan over Greenland

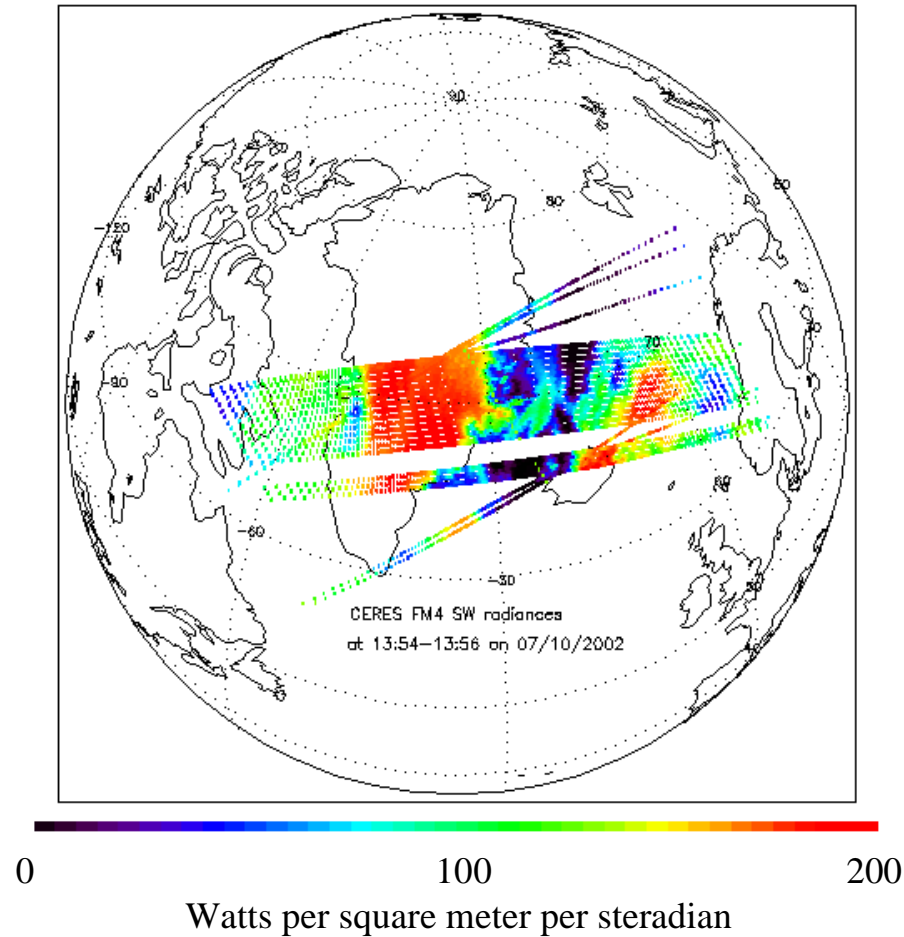
Unfiltered shortwave radiances at 13:40 on 07/10/2003



0 100 203  
Watts per square meter per steradian

# FM4 scan over Greenland

Unfiltered shortwave radiances at 13:54 on 07/10/2003





# Why Greenland?

Observation site which is the most homogenous:

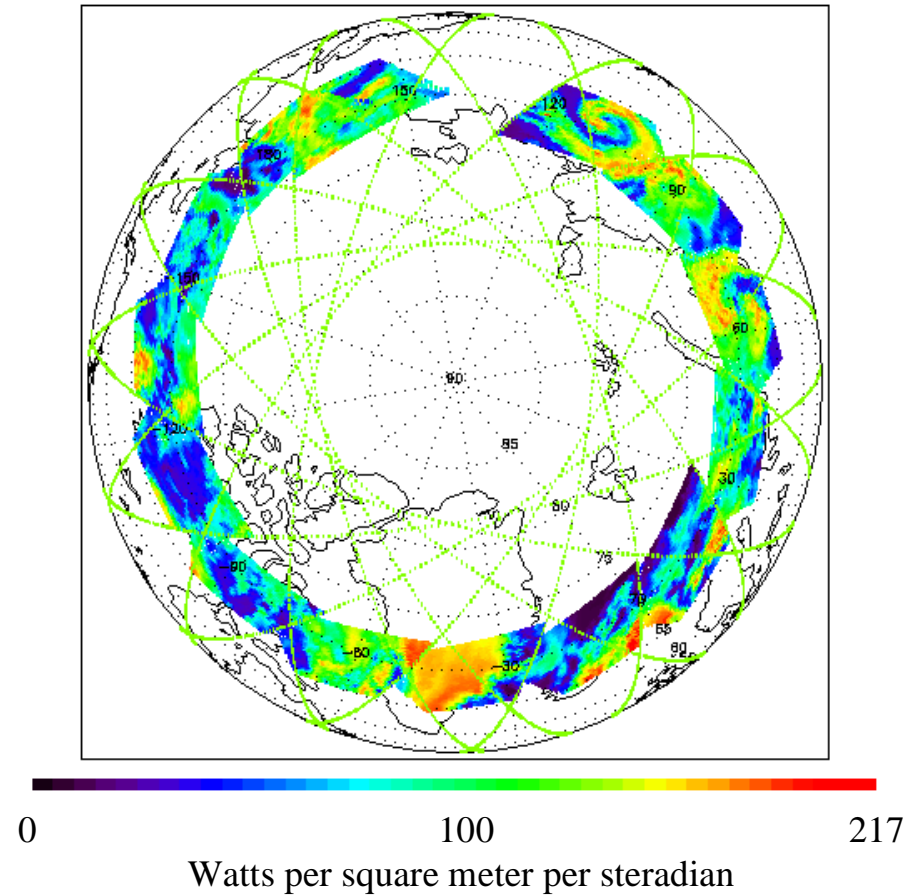
- FM1 and FM4 15 minutes apart
- Scans orthogonal to the solar plane
- Scanning in every orbit for different scene types

Validation campaign:

- 07/04 – 08/22, 2002
- 1,000 orbital crossings of about 90 seconds each
- Significant amount of data for statistical analysis

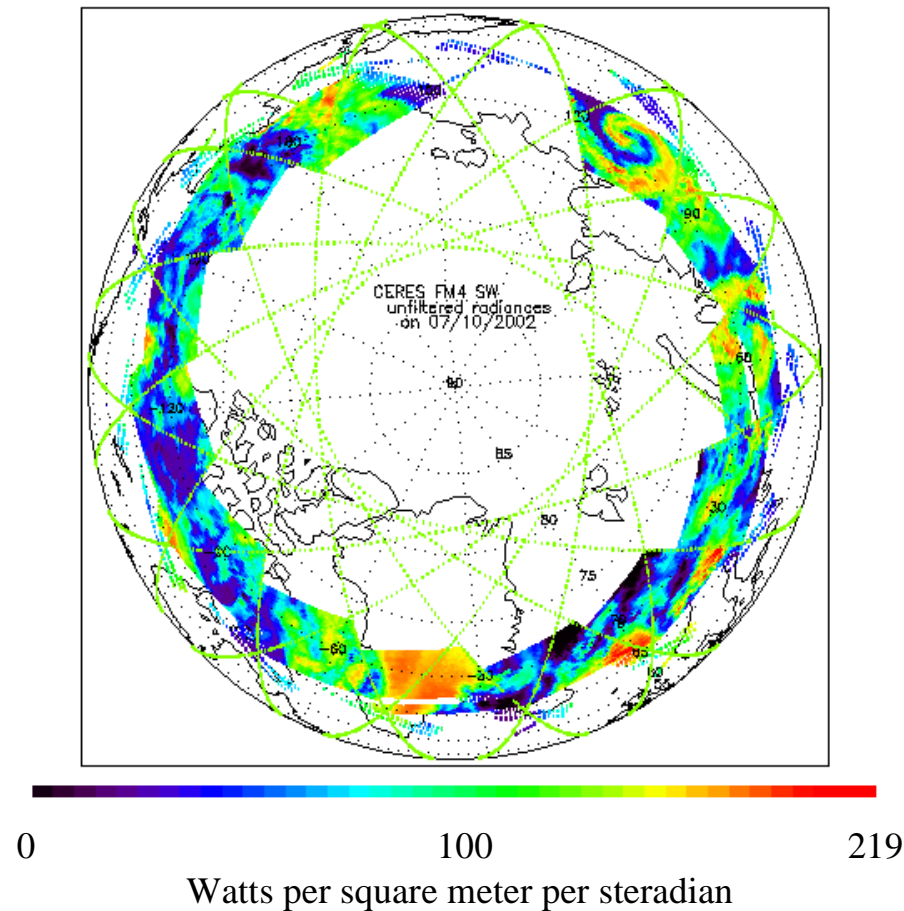
# FM1 scanning pattern

Unfiltered shortwave radiances on 07/10/2003



# FM4 scanning pattern

Unfiltered shortwave shortwave on 07/10/2003



# Data processing constraints

Direct comparison of radiances:

- difference of averages

No time issue:

- Terra – Aqua 15 minutes apart

Spatial noise dominates:

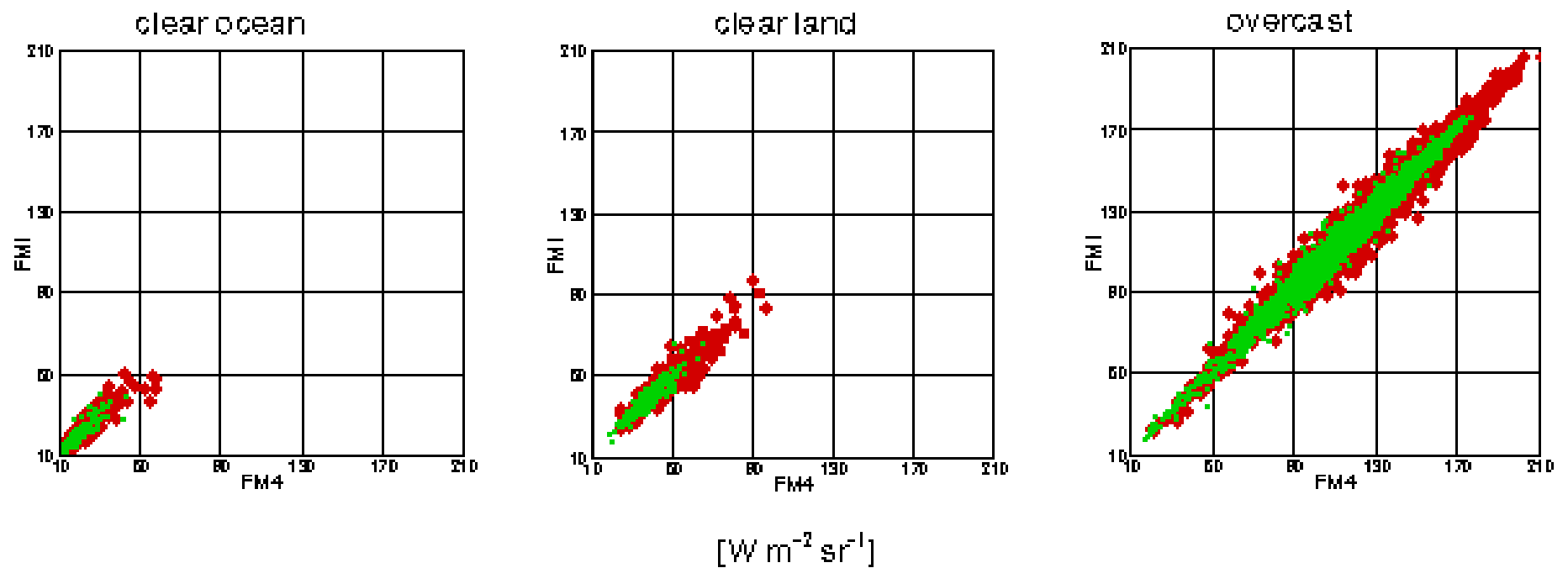
- averaging over  $1^\circ \times 1^\circ$  grid-boxes
- at least 20 footprints or 75% of area covered

Matching geometry:

- $10^\circ$  tolerance for viewing zenith for all three channels
- $20^\circ$  tolerance for relative azimuth to the Sun for shortwave

# Shortwave radiances

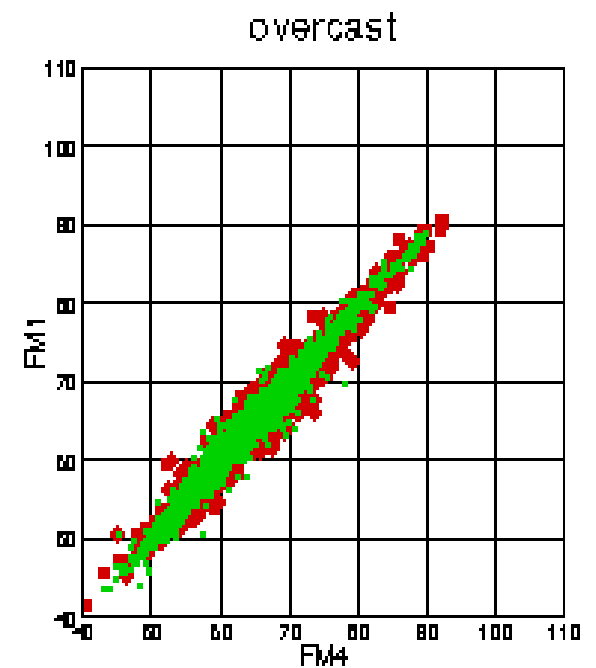
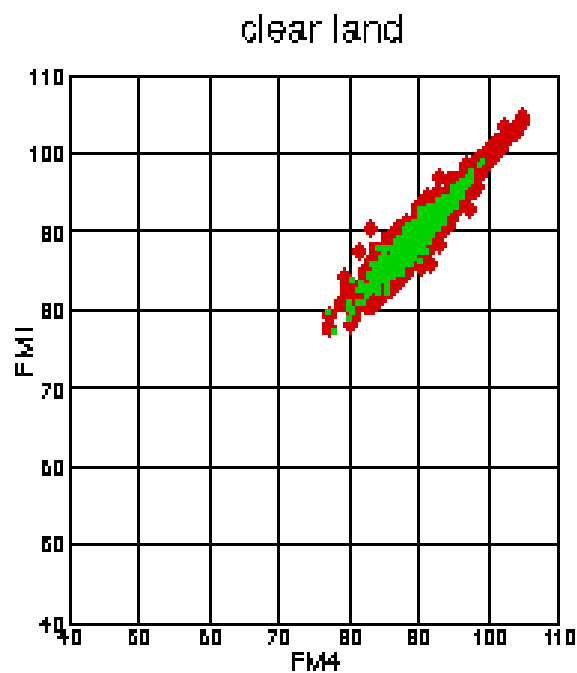
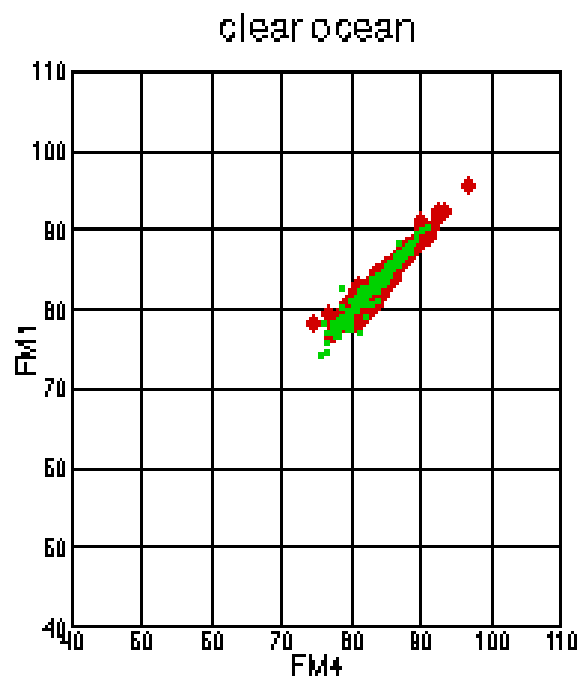
■ July      ■ August



# Longwave radiance - daytime

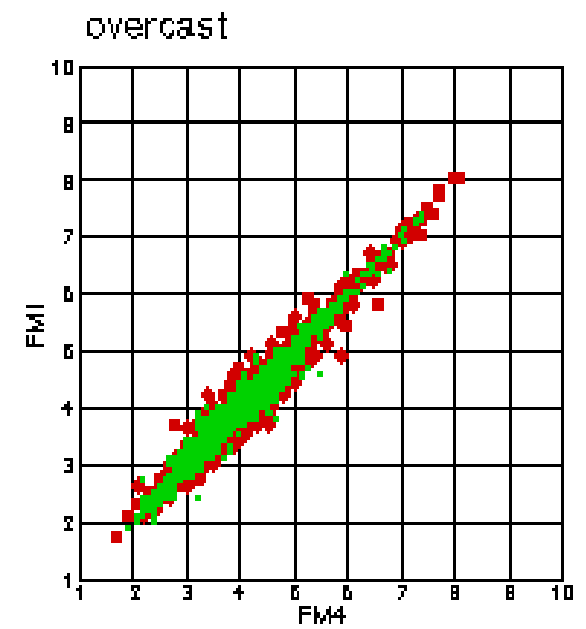
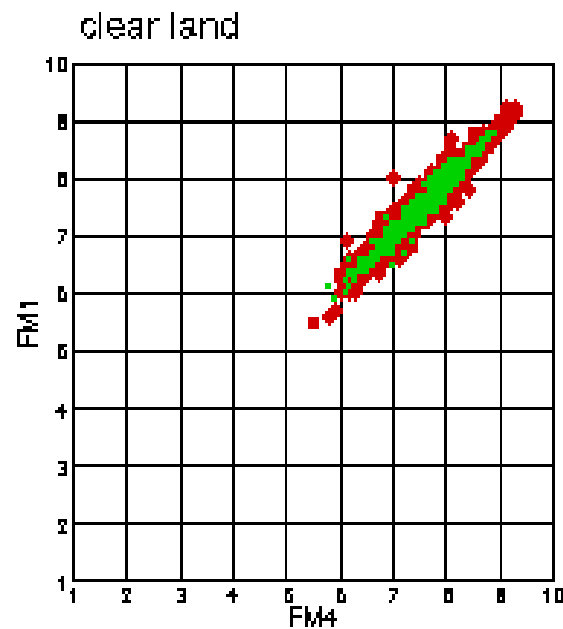
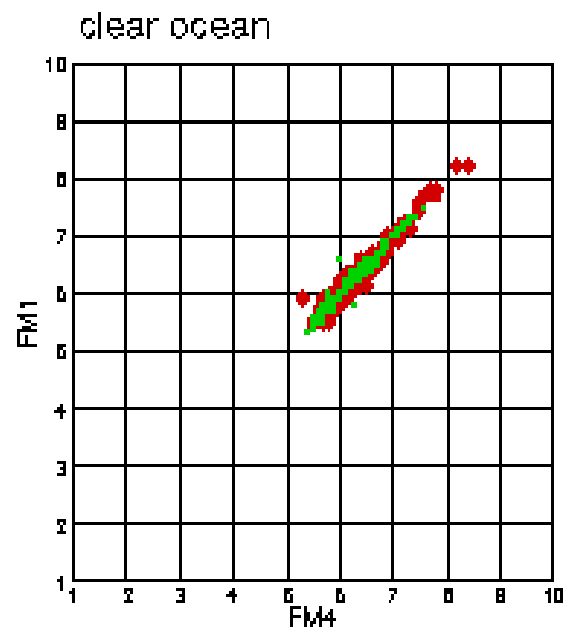
● July

● August



# Window channel - daytime

● July      ● August

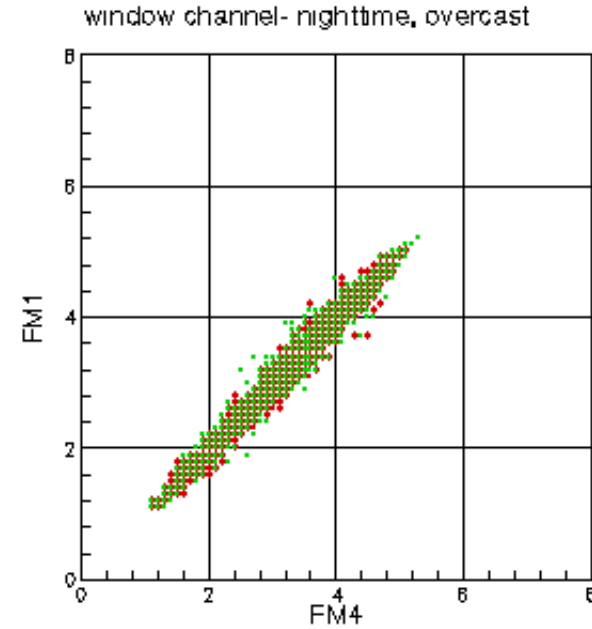
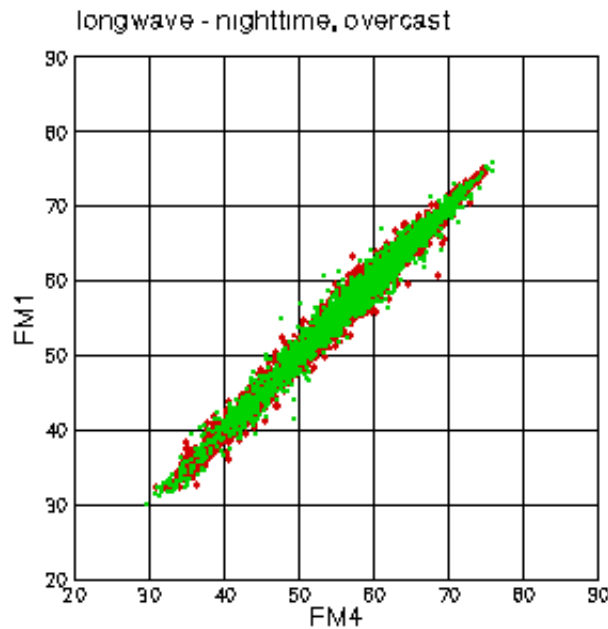


$[W m^{-2} sr^{-1} \mu m^{-1}]$

# Nighttime radiances over Antarctica

● July

● August





# Statistics

## Direct comparison of radiances:

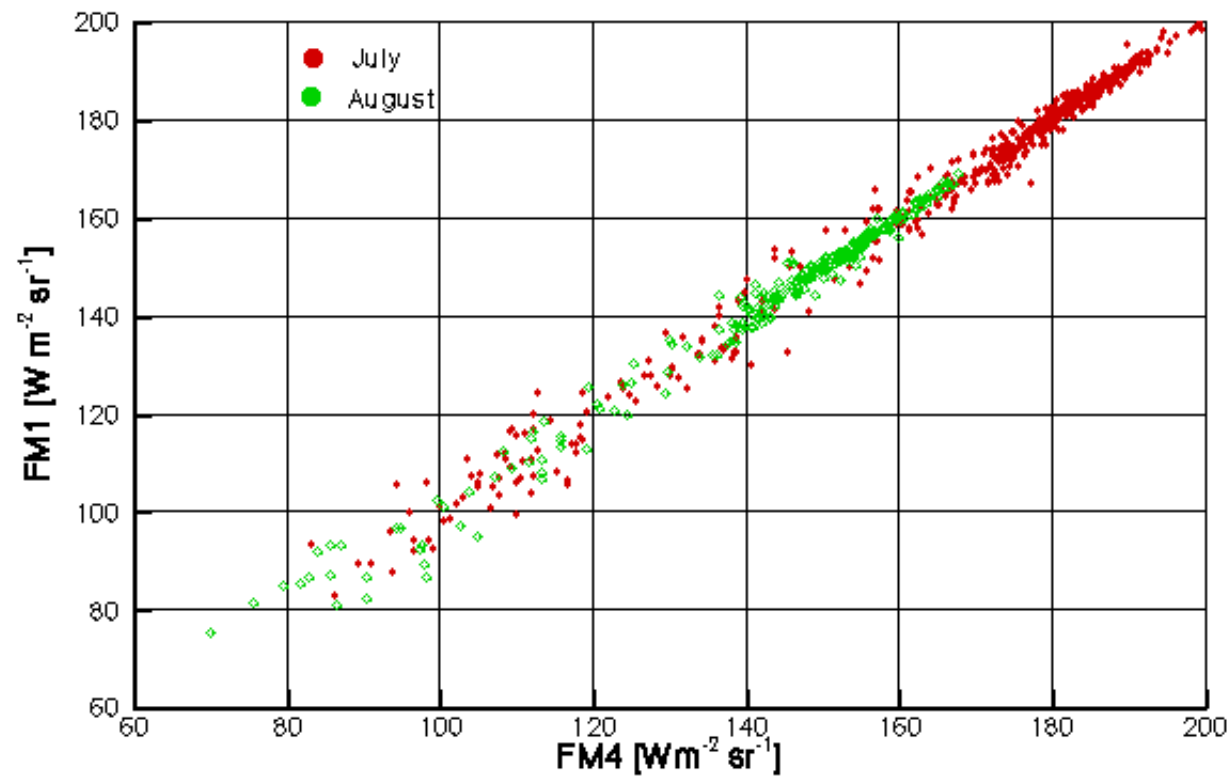
- Difference over a grid-box and orbital crossing
- Each orbital crossing is an independent sample
- Uncertainty estimated using a 95% confidence level

$\alpha$  – test: 
$$\varepsilon = \frac{t_{\alpha/2} \sigma}{\sqrt{N}}$$

# Results for all data collected

Radiance	Mean FM4 [Wm <sup>-2</sup> sr <sup>-1</sup> ]	$\Delta$ mean [Wm <sup>-2</sup> sr <sup>-1</sup> ]	$\Delta$ mean %	$\Delta\sigma$ [Wm <sup>-2</sup> sr <sup>-1</sup> ]	N <sub>orbX</sub>	$\alpha$ -test
SW	88.6	-0.36	<b>-0.4</b>	0.74	508	<b>0.08</b>
LWday	76.7	0.54	<b>0.7</b>	0.18	508	<b>0.02</b>
LWnite	55.1	0.06	<b>0.1</b>	0.1	527	<b>0.01</b>
WNday	5.5	0.05	<b>0.9</b>	0.03	508	<b>0.00</b>
WNnite	3.0	0.03	<b>1.0</b>	0.01	527	<b>0.00</b>

# SW radiances over Greenland



# Results for Greenland

Radiance	Mean FM4 [Wm <sup>-2</sup> sr <sup>-1</sup> ]	$\Delta$ mean [Wm <sup>-2</sup> sr <sup>-1</sup> ]	$\Delta$ mean %	$\Delta\sigma$ [Wm <sup>-2</sup> sr <sup>-1</sup> ]	N <sub>orbX</sub>	$\alpha$ -test
SW	159.1	0.24	<b>0.15</b>	1.05	72	<b>0.3</b>

# Conclusions

- Validation procedure for FM1 and FM4 was shown to be well planned and executed
- Data analysis fully demonstrated **the 1% consistency** in radiance measurements
- Experiment was repeated in **June, 2003** in an effort to further monitor CERES performance
- CERES instruments have delivered a high quality radiation budget data set **since 1998**